(21) Application No 0007111.8

(22) Date of Filing 23.03.2000

(30) Priority Data
(31) 0002547   (32) 03.02.2000   (33) GB

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(51) INT CL7
H04Q 7/38 , G01S 5/14

(52) UK CL (Edition T)
H4L LRPLS L209

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(58) Field of Search
UK CL (Edition S) H4L LDGR LDPB LRPLS
INT CL7 G01S 5/14 , H04M 3/42 11/08 , H04Q 7/38
Online: WPI,EPODOC, PAJ, IEEE and selected internet
sites

(54) Abstract Title
Locating system

(57) A locating system for a mobile station of a cellular communications network which uses a locating system computer 140 that compares a normal network measurement report (NMR) 110 (which contains results regarding signal strength from and identities of the serving cell and neighbouring cells) with a network profile database 142. Based on the comparison the latitude and longitude (location) of a mobile station can be computed. The NMR may be validated and synchronised prior to supplying it to the computer. The locating system may comprise a network statistics database 144 used to identify seven adjacent cells and to apply network handover statistics to calculate vicinity information of each identified cell. The system may then further select the three nearest cells and provide the location of the mobile station as the centroid of these three cells. In an alternate embodiment the NMR is compared with a vector quantization codebook 146 and the location is provided based on the matching cell ID only. An alternative embodiment relates to selecting one of a plurality of location determining algorithms in response to the identity of the cell serving the mobile station.
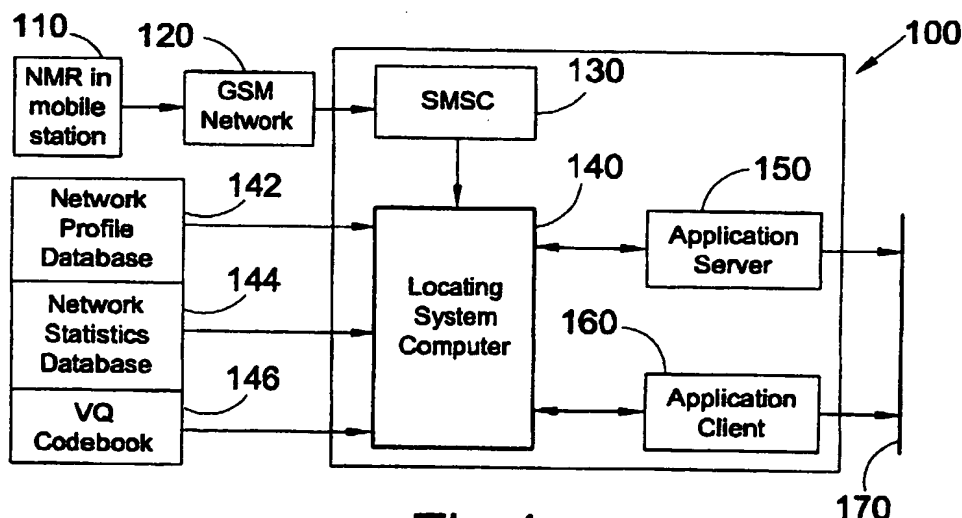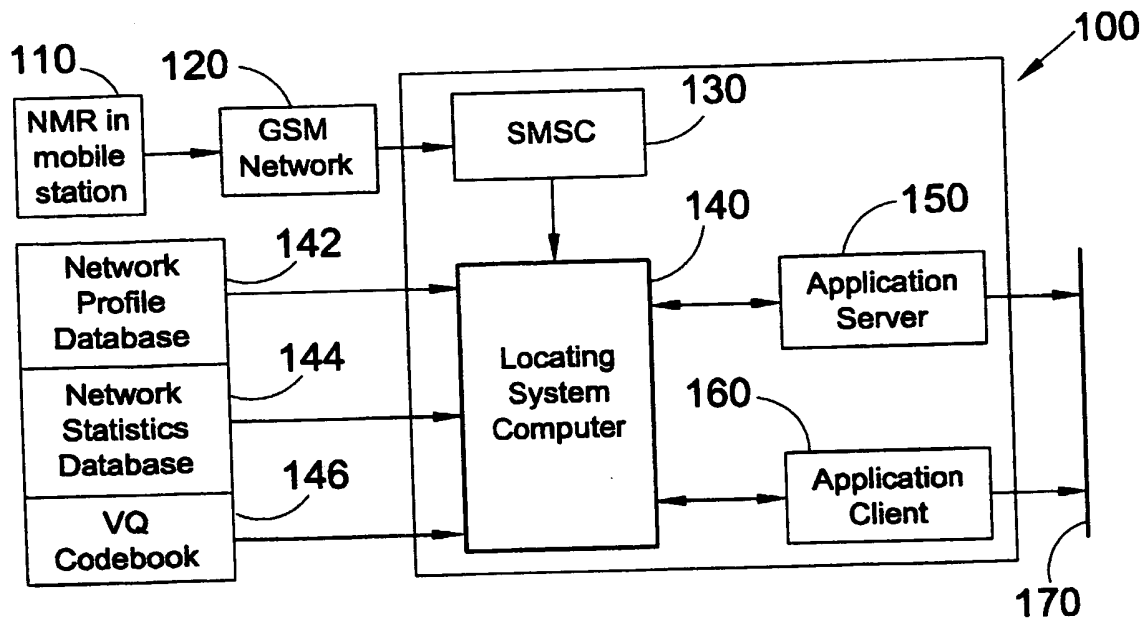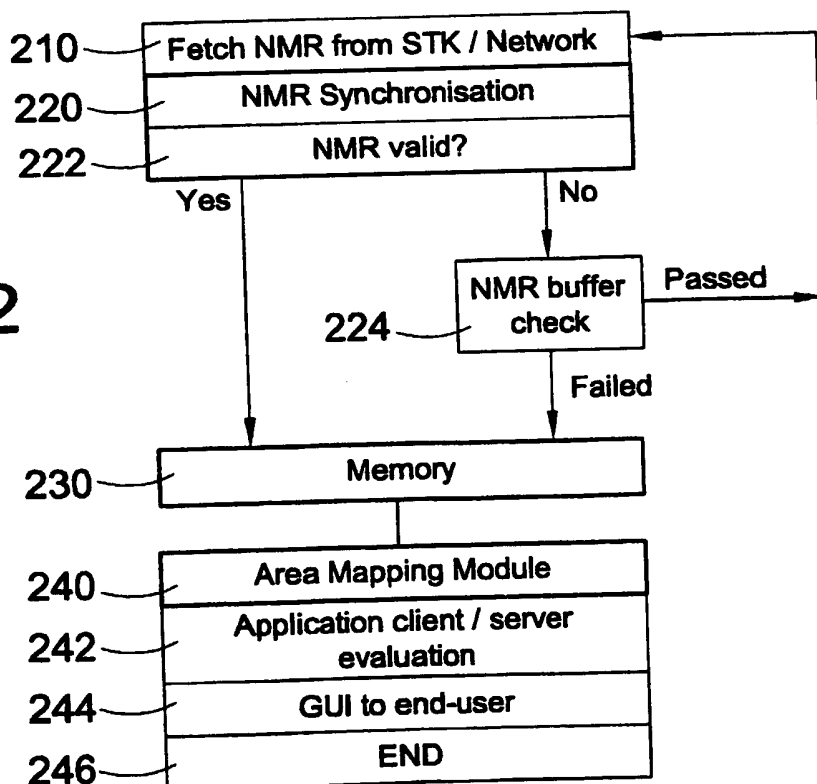
Fig.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1

Fig.2

Fig.3

Fig.4

510 — Begin NMR validation

520 — Fetch NMR

530 — Check the presence of serving cell ID

No →

540 — ΣNMR <=3? (buffer check)

Passed

Failed

Yes ↓

550 — Neighbour Cell Mapping Module

560 — Calculate distance for neighbour cells

570 — Distance < threshold?

No →

Yes ↓

580 — End NMR validation
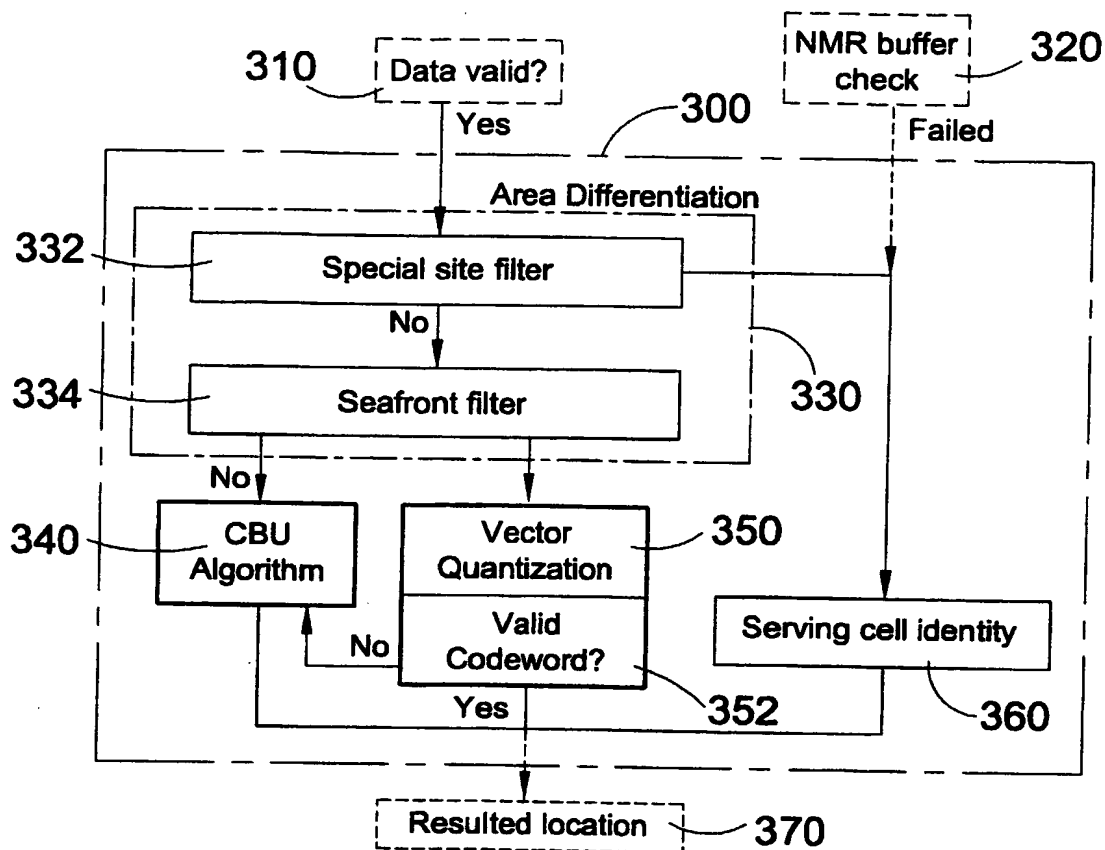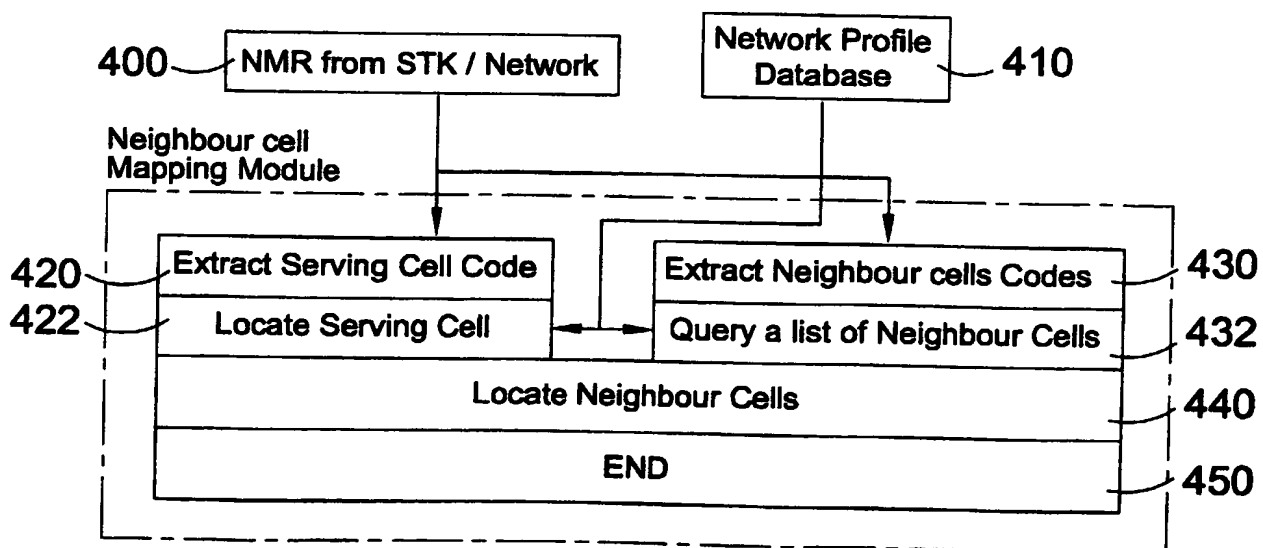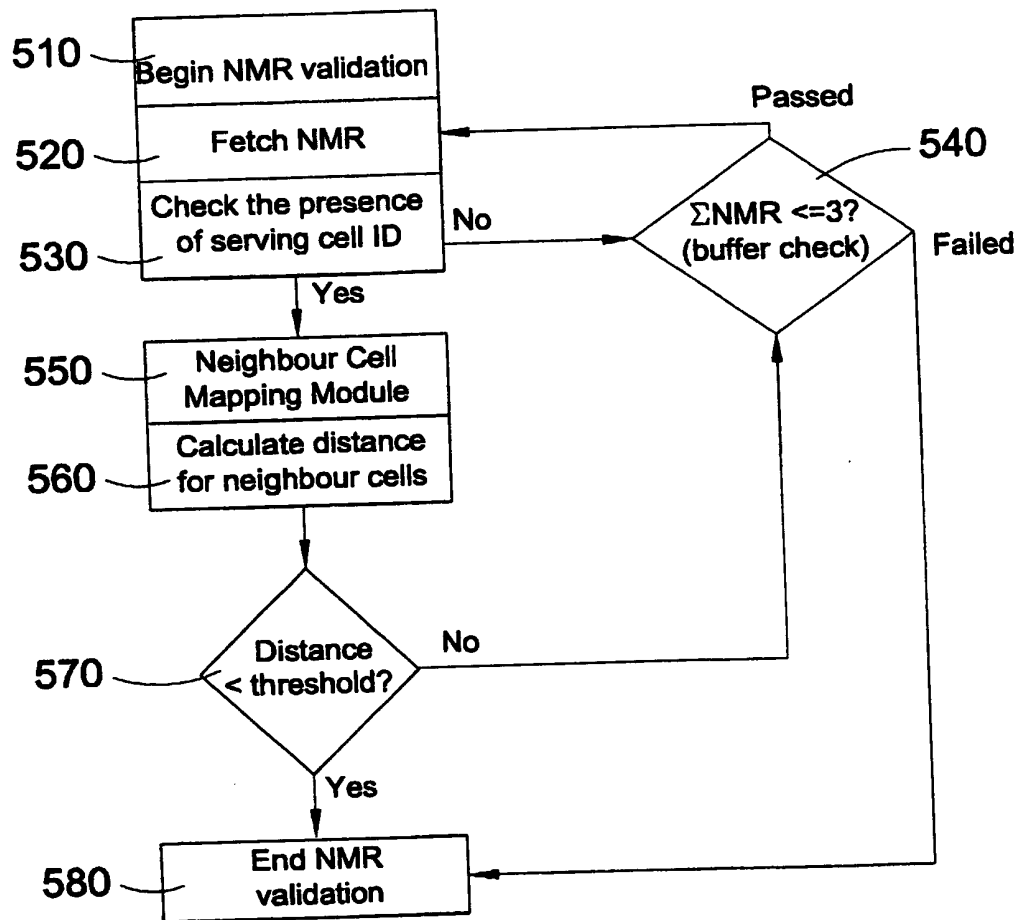
Fig.5

LOCATING SYSTEM

This invention relates to locating systems for mobile communication units.

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A "Second Generation" of mobile communications industry has come to a stage where voice only services may not satisfy subscribers' needs and ensure further growth for mobile network operators. For Global System for Mobile Communications (GSM), in particular, the short message services and Unstructured Supplementary Service Data (USSD) have already provided a platform for developing information services applications.

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The Unstructured Supplementary Service Data (USSD) procedure is used to trigger the ISE service because it provides a more simple and easy to use user interface platform for subscribers. USSD enables a mobile user to invoke and control supplementary services, that are :

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-     not supported by the mobile user's mobile equipment, i.e. the needed functionality (e.g. signalling) is not implemented in the mobile.

-     non-GSM supplementary services for which no functional signalling is defined.

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ETSI/GSM 02.90 & ETSI/GSM 02.30 have defined the rules for constructing a USSD procedure. The mobile station (MS) shall support the MMI procedure specified as:

Activation   : *SC*SI#

Deactivation   : #SC*SI#

Interrogation : *#SC*SI#

Registration   : *SC*SI# and **SC*SI#

Erasure   : ##SC*SI#

The structure consists of the following parts :

   - Service Code, SC (2 or 3 digits)

   - Supplementary Information, SI (variable length)

The procedure always starts with *, #, **, ## or *# and
ends with #. Each parameter within the procedure is
separated by *.

A unique SC is used to define each Supplementary
Service. The SI can be comprised of say a stock code or
a PIN code. When a particular request does not require
any SI, "*SI" is not entered. When more than one piece
of supplementary information is required, the SIs can
be entered consecutively, e.g. **SC*SIA*SIB#SEND.

The use of SIs, SIA, SIB and SIC, in a particular
procedure is optional. *SI# shall be entered in any of
the following formats:

   - *SIA#

   - *SIA*SIB#

- *SIA*SIB*SIC#

- *SIA**SIC#

- **SIB#

- ***SIC# etc...

The advent of SIM Application Toolkit (STK) gives even much flexibility to program the SIM card for more sophisticated applications. Geographical locations applications of mobile handsets (or units) have utility for fleet management, location-based services and on-the-spot advertisements. Many such proposals are available in the market, however their order of accuracy and requirements in network architecture, mobile handsets and SIM cards are not generally not compatible.

The most commonly known locating or positioning system is the Global Positioning System (GPS). A constellation of 24 NAVSTAR (TM) satellites circles the Earth every 12 hours emitting radio signals identifying their positions. GPS uses spread spectrum that enables use of very low received signal levels. The claimed accuracy can be up to 100 metres. It can be further enhanced to 5-10 metres by using the Differential GPS (DGPS). However, the high cost and non-availability of a GPS inside GSM mobile handsets make this unsuitable. Moreover, in some dense urban areas there may be a problem in receiving signals because of there being too

few satellite signals available.

There are several types of GSM-based locating or positioning techniques, namely, cell identity (cell ID), time advance (TA), time of arrival (TOA), enhanced observed time difference (E-OTD), and angle of arrival (AOA).

Using cell identity (cell ID) as a reference location is a simple and straightforward solution, which involves no software or hardware changes at all. However, its accuracy is heavily dependent on the network topology and site-to-site distance that could range from 100 metres to 30 kilometres. Time advance (TA) might carry more information in a distance sense. But, it requires some software changes in the GSM network and it is only good for applications requiring low accuracy, say up to one kilometre. Differences between the times of arrival (TOA) of signal from a handset at three Base Transceiver Station (BTS) can be used to calculate the location of the mobile handset. Although accuracy may be 125 metres or below, required expensive network infrastructure includes Location Measurement Units (LMU) and a highly accurate clock, GPS or atomic clock, to synchronize the different Base Station Controllers (BSC) involved.

The hardware requirement for Angle of Arrival (AOA) is

similar to that of TOA. AOA uses a beam forming technology, which makes use of the sophisticated and expensive antenna arrays to determine the directions of signal arrival. However, accuracy is severely degraded if there is no clear line of sight. The use of enhanced observed time difference (E-OTD) needs additional Location Measurement Units (LMU) for the Base Transceiver Station (BTS) and modifications in the mobile handsets. Although the accuracy may be up to 125 metres or better, expensive network infrastructure is required.

It is an object of the invention to overcome or at least reduce these problems.

According to one aspect of the invention there is provided a locating system for a mobile station which comprises a locating system computer, the system supplying a normal network measurement report (NMR) for the mobile station to the computer, comparing the NMR with a network profile database, and computing resulted latitude and longitude for the mobile station where a suitable comparison is found.

Steps of validating and synchronising the NMR prior to supplying the NMR to the computer may be included.

The locating may be carried out using a network statistics database for comparison in the computer, the database is derived using an algorithm to find the cell identity (ID) of seven most important adjacent cells, as measured by the mobile station, applying network handover statistics to calculate vicinity information of each cell, selecting the three nearest cells according to the calculation, and providing the resulted latitude and longitude as a centroid of the latitudes and longitudes of the three cells.

The locating system may include comparing the NMR with a vector quantization (VQ) code book that contains codeword locations for cells located at special regions of the network, providing the resulted latitude or longitude based on any matching cell ID only.

According to another aspect of the invention there is provided a method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising the steps of identifying three cells in the vicinity of the mobile station, each said cell having a cell location; and determining an approximate position of the mobile station using the locations of the three cells.

The approximate position of the mobile station may be determined by calculating a centroid of a triangle formed by said three cells.

5   The said three cells may be selected from a plurality of candidate cells neighbouring a serving cell for the mobile station.

A said neighbouring cell may be determined using at
10   least one system parameter relating to the mobile station selected from a group including an ID of the serving cell, an ID of a base station in communication with the mobile station, and a candidate neighbouring cell frequency channel.

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A said neighbouring cell may be determined using a database comprising cell mapping data defining physical cell locations.

20   The said three cells may be selected from six candidate neighbouring cells.

The method may comprise measuring, for each neighbouring cell, a signal strength for a signal
25   transmitted between the mobile station and the neighbouring cell; and selecting said three cells using the measured signal strengths and a database of cell-to-neighbour-cell handover statistics.

The method may include calculating, for each neighbouring cell, a value representing a probability of a successful handover to that cell, and wherein said selecting is responsive to the calculated probability.

The said plurality of candidate neighbouring cells may include a cell identified as a handover target cell in a or the said database of cell-to-neighbour-cell handover statistics.

The approximate position of the mobile station may be determined using only the serving cell identity rather than by identifying three cells in the vicinity of the mobile station.

According to a further aspect of the invention there is provided a method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising the steps of using a compressed system parameter report to look up an approximate mobile station location in a vector quantization codebook.

According to a yet further aspect of the invention there is provided a method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising selecting one of a plurality of

location – determining algorithms responsive to the identity of a cell serving the mobile station.

Embodiments of the invention make use of screening filters to partition the locating system into three entities, which enables the use of area differentiation upon the measurement reports. A knowledge-based heuristic algorithm can be used to enhance the accuracy of locating system compared to only using cell identity. Also, a codebook using vector quantization can be used to model radio characteristics of some special or specific, such as sea-front regions, regions in the GSM network, which can be applied via compressed measurement reports.

Locating systems for mobile telephones according to the invention will now be described by way of example with reference to the accompanying drawings in which :-

Figure 1 shows schematically an overall architecture for the locating system and inputs for the system;

Figure 2 is a flow diagram of the operation from retrieval of Network Measurement Reports (NMR) to the output of calculated location-based information;

Figure 3 shows a functional flow diagram for the operation of calculating a location from valid or

partially valid data within the locating system;

Figure 4 shows a neighbour cell mapping module for decoding the NMR for neighbour cell information, which is applicable to processes in the locating system; and

Figure 5 is a flow chart for NMR validation and synchronization processes.

Referring to the drawings, in Figure 1 a normal network measurement report (NMR), or other GSM features, is collected from a mobile telephone or station 110 using an SIM Application Toolkit (STK) in the mobile station 110. A normal report has been defined in ETSI/GSM 04.08 (9.1.20) and refers to the measurement data collected from both the mobile station and the BTS (Base Transceiver Station). It will be sent from the BTS to the BSC (Base Station Controller).

The entire information in the NMR is not used, only the entity called 'Measurement Results'. The content of the 'Measurement Result' is well defined in ETSI/GSM 04.08 (10.5.2.11). The 'Measurement Result' is recorded by the mobile station and will be sent to the BTS for evaluating handovers. The following information inside the 'measurement result' is used :

- serving cell identity
- serving cell signal strength as received by mobile

station

- serving cell broadcast channel / frequency (BCCHNO) and base station identity code (BSIC)

- Six pairs of neighbouring cell broadcast channels / frequencies (BCCHNO) and base station identity code (BSIC)

- SIX neighbouring cells' signal strength as received by the mobile station

The locating process can be either triggered by a subscriber or by the locating system in a central controller of the network. The NMR is transmitted through a GSM network 120 over a Short Message Service (SMS) bearer, or other suitable bearer such as General Packet Radio Service (GPRS) 130. This is applicable to a single 900-band GSM network, a single 1800-band GSM network and a 900/1800 dual-band GSM network 120. A locating system central location system computer 140 collects the NMR as its primary input.

Two databases provide statistics and network background data to the computer 140 as secondary inputs. Network statistics database 144 provides cell-to-neighbour cells handover statistics. A network profile database 142 provides a map of the communications network with pre-defined areas, site locations, including latitude and longitude, the network base station BSC parameters of cell names, cell global identity (CGI), broadcast

channel (BCCH) and base station "colour code" (BSIC).

The generation and storage of the mapping data can be provided in two ways. The first way is a two-stage searching algorithm. It involves generating and storing mapping data as follows:

1. define the entire city / country map into a certain number of meaningful areas.

2. mark the areas on the digitized map using a geographical software tool called MapInfo$_\wedge^{(RTM)}$.

3. export a table from MapInfo to extract the latitude-longitude pairs for different areas.

4. as this provides the area name, latitude and longitude information in one table, apply any location with latitude and longitude to determine the belonging area by searching through this table.

The searching speed may be too slow for a large city. If so:

To increase speed, generate a number of grid tables defining corners of the grid squares at different resolutions. An entire city is divided into 100 squares (10x10) using a relatively low resolution. The latitude

and longitude of all corners of those 100 squares are stored into a table (T_0). Generate another 100 tables (T_1 – T_{100}) similar to the first table but with a relatively higher resolution and also containing the area name for each point. Then locate the mobile station in T_0 by given latitude and longitude. Identify the square, go to the specified table out of T_1 – T_{100} to look for the area name.

The second way uses the steps 1 and 2 above. Thereafter MapInfo's function call is used to extract the area name. This function call can be implemented using Visual Basics (RTM) or Visual C++.

A Vector Quantization (VQ) codebook 146 contains the up-to-date compressed NMRs as codewords for location look-ups in specified sea-front regions or other special regions. This is tertiary input for the computer 140.

Added components of the system include applications server(s) 150 and application client(s) 160. Their specifications are open and such components are not part of the present invention but represent building blocks for future development. For example, an application server could be a vehicle tracking system for fleet management. While for individual usage, an application client could become a location-based

shopping guide. However, both client and server applications can share the same protocol towards locating system that consists of resulted or calculated locations with latitude and longitude, time-stamps and the matched areas. Some applications may require connections from the application server to another database server or data warehouse 170 for example, which could make the locating system a 3-tier or even an n-tier system.

In Figure 2, the flow diagram of the operation between retrieval of NMR to an output of calculated location-based information for the location system comprises the following steps:

STEP 210: Begin fetching NMR (or other GSM features) from the STK in the mobile station 110 via the GSM network 120 and Short Message Service Center (SMSC) 130.

STEP 220: The NMR is decoded inside the computer 140 and a validation index is calculated for justification.

STEP 222: The validation index may be checked against an experimental value, or applying a synchronisation step (see below). If the NMR is valid, it is fed into a memory 300 as its input.

STEP 224: If NMR is not valid, a buffer is checked for additional NMR. If such NMR is available, the process starts again STEP 210. If not, the NMR is deemed to be

invalid, and the most reliable NMR will be used by the memory 300.

STEP 230: The memory 300 uses the NMR to determine a resulted location, latitude and longitude of the mobile station.

STEP 240: An area-mapping module computes a matched area from a map using the resulted latitude and longitude 370.

STEP 242: The mobile station evaluates the results from the computer 300.

STEP 244: The results are displayed on a graphical user interface (GUI). The display can be varied from text-based only, bundled with information from another database or be a map display with flashing and zoning features.

STEP 246: Ending the procedure of the Positioning System triggers a closed session for both the STK 110 and SMSC 130 data channel connection.

Figure 2 includes step 220 that comprises an NMR synchronization step. A full NMR comprises the serving cell information and the neighbour cell information. The serving cell information is trusted whenever the serving ce'll identity (serving cell ID) is present. However, the neighbour cell information may not be synchronized with the serving cell information. The current neighbour cell information may belong to the some other previous NMR, having a different serving

cell ID from that in the current NMR in a worst case. Possible reasons for a synchronization problem includes there being different designs or performances in updating NMR for different mobile handsets, the NMR being only partially updated during an idle mode, or some parts of the NMR not being updated after a recent handover.

For dealing with this situation, the NMR validation step shown in Figure 5 is as follows :-

STEP 510: Begin the NMR validation step or process.

STEP 520: Start fetching an NMR from a buffer.

STEP 530: Check whether the NMR contains the serving cell ID information.

STEP 540: If there is no serving cell ID in the NMR, the NMR should be discarded. The buffer size for the number of different NMR data is three. If there is one or more NMR left in the buffer, the NMR is fetched and the procedure starts again from STEP 520. If none of the NMR's have a serving cell ID, the perceived most reliable NMR among the three NMRs in the buffer is used.

STEP 550: A Neighbour Cell Mapping Module (as explained below with reference to Figure 4) is used to decode neighbour cell messages and determine the corresponding neighbour cells.

STEP 560: The distances from the serving cell to all

neighbour cells are calculated, the longest distance or the average distance is used as a synchronizing index.

STEP 570: If the distance (synchronizing index) exceeds a pre-set threshold (an empirical or recorded data value, that may be changed on the fly) the system will try another NMR left behind in the buffer, if any.

STEP 580: End the NMR validation and synchronization process.

The location system makes use of a neighbour cell mapping module. Figure 4 is a flow diagram of use of the neighbour cell mapping module for decoding the NMR for deducing neighbour cell identities, and comprises the following steps:

STEP 400: Take NMR (or other GSM features) from the SIM Application Toolkit (STK).

STEP 410: Take data from a network profile database 142 that serve as look-ups for cell identities and site locations.

STEP 420: Input serving cell codes. This is a 16-bit word and should be less than 65535, it can be extracted directly from the NMR and is included in normal GSM specifications.

STEP 422: Check serving cell location by longitude and latitude from the network profile database 142.

STEP 430: The codes extracted for neighbour cells are the broadcast channel (BCCH) and the base station

colour code (BSIC).

STEP 432: Each particular (BCCH, BSIC) combination is a one-to-many mapping function to the cell identities in the network profile database 142. There may be a number of identical BCCH and BSIC found. This is because each is reused throughout any GSM network; identical combinations will however be widely spaced apart or geographically separated by other cells. In any event, a list of potential neighbour cells may be found after mapping for a six pairs of (BCCH, BSIC) combinations.

STEP 440: In order to locate the correct neighbour cells, distances from all potential neighbour cells 142 to the location of the current serving cell 422 are calculated. By applying a minimum function to the distances of neighbour cells for every (BCCH, BSIC) pair, the identities for the six neighbour cells can easily be deduced, even where identical pairs crop up.

STEP 450: End the neighbour cell mapping module.

In order to calculate the location of a mobile telephone a functional flow diagram for the operation of a calculation from the valid or partially valid data within the computer 300 is now described with reference to Figure 3.

Two filters within an area differentiation module 330 determine the appropriate algorithm to be applied to a current NMR. Normally, details and identification of

special sites and partially valid NMRs 320 are based on the serving cell ID 360 within the NMR data only. In case of the serving cell of the valid NMR 310 lying within a special sea front region, for example, a Vector Quantization 350 will be used. Otherwise, an CBU Algorithm 340 (explained below) will be applied. The resulted location 370 will be passed on to an area mapping module 240.

The two screening filters to partition the positioning system into three entities.

A special site filter 332 looks up a list of the special sites from the network profile database 142 using the serving cell information in the current NMR. The special sites could be a sea front region, a vehicle tunnel or an underground station where the location of the cell is known and geographically well-defined. Whenever matching is found in the list, the location evaluation will be based only on the serving cell ID 360. The definition of special site is invariably an GSM base station serving a very confined area and having very little overlapping with its neighbour cells. By making use only of the ID information of these special sites, an accurate resulted location 370 can be produced in a speedy manner.

The sea front filter 334 makes use of a table from the network profile database 142, which identifies boundaries of all the important sea front regions in terms of longitude and latitude. If the location of the serving cell is bounded by a sea front boundaries, Vector Quantization 350 will be applied as the preferred algorithm. Otherwise, the (default) Algorithm 340 will be applied.

The Algorithm 340 is applied to work out the resulted location 370 from a current valid NMR 310 by looking through a network profile database 142 and network statistics database 144. This algorithm is applied in three phases.

Phase 1 involves the extraction of the cell identities for seven most importantly related cells, which is measured by and based on NMR from the mobile station. The serving cell ID is immediately available from the current valid NMR 310 while the other six neighbour cell mapping module has been described with reference to Figure 4. The received signal strength values are piggy-backed to the cell identities forming a group of SEVEN pairs of NMR cell information F: $(F_{k,1}, F_{k,2})$, where k=0, 1, 2, 3, 4, 5, 6:

$F_{k,1}$ = cell ID received by the mobile station

$F_{k,2}$ = signal strength for the kth cell perceived by the mobile station

Note that k = 0 refers to serving cell information.

Phase 2 requires two input sources, one of them is the NMR cell information F: $(F_{k,1}, F_{k,2})$ while another one is the matrix of handover statistics H: $(H_{q,1}, H_{q,2}, H_{q,3})$, where q=1, 2, ..., N.

Suppose that:

N = total number of handover relations in the entire network

M = total number of cells in the entire network

P(r) = total number of handover relations originating from the rth cell, different cells may have different values

then,

$H_{r,1}$ = current originating cell ID

$H_{s,2}$ = current target handover cell ID from cell $H_{r,1}$

$H_{q,3}$ = historical number of successful handovers from cell $(H_{r,1})$ to relation $(H_{s,1})$

where r=1, 2, ..., M and s=1, 2, ..., P(i)

The next step is to generate a new matrix U from the matrices F and H by applying the criteria $H_{r,1} = F_{k,1}$,

where k=0, 1, 2, 3, 4, 5, 6. The entities for matrix U are

defined as follows:

Matrix U: $(U_{a,1}, U_{a,2}, U_{a,3})$, where a=1, 2, ..., A   (A is

the total number of relations for the 7 cells in F.)

Suppose that:

$m(r)$ = the maximum count of successful handover

among all handover relations for a particular

originating cell $(H_{r,1})$

then,

$U_{a,1} = H_{r,1} = F_{k,1}$

$U_{a,2} = H_{s,2}$

$U_{a,3} = F_{k,2} * H_{q,3} / m(r)$

Thus, $(U_{a,3})$ is the product of received signal strength

and successful handovers being normalized by the

maximum count of successful handovers of a particular

originating cell. $(U_{a,3})$ is termed as the reference

index.

Another matrix V is generated from matrix U in order to

sum up all the reference index values for every unique

target handover cell $(U_{a,2})$.

Matrix V: $(V_{b,1}, V_{b,2})$, where b=1, 2, ..., B   (B is the

total number of distinct target handover cells in U.)

$V_{b,1}$ = any of the distinct elements in $U_{a,2}$

$V_{b,2}$ = $\sum(U_{a,3})$ for all $(U_{a,2} = V_{b,1})$ AND $(V_{c,1} = V_{b,1}$

where

$c \neq b)$

Now matrix F contains the vicinity information for the SEVEN cells in the NMR while matrix V contains the reference index values which can be used to infer the location of the mobile station. To combine matrices F and V, another matrix W is formed.

Matrix W: $(W_{d,1}, W_{d,2})$

For d=0 to 6,

$W_{d,1}$ = $F_{k,1}$

$W_{d,2}$ = α * $F_{k,2}$

where k=0, 1, 2, 3, 4, 5, 6; α=2.5 which is a weighting factor applied to the SEVEN cells in NMR

For d=7, 8, —, (B+7)   (B is the total number of distinct target handover cells in U.)

$W_{d,1}$ = $V_{b,1}$

$W_{d,2}$ = $V_{b,2}$

Another matrix Z is generated from matrix W in order to sum up all the reference index values for every unique cell $(W_{d,1})$ in W.

Matrix Z: $(Z_{e,1}, Z_{e,2})$, where e=1, 2, ..., E (E is the total number of distinct target handover cells in W.)

$Z_{e,1}$ = any of the distinct elements in $W_{d,1}$

$Z_{e,2} = \Sigma(W_{d,2})$ for all $(W_{d,1} = Z_{e,1})$ AND $(Z_{f,1} = Z_{e,1}$

where

$f \neq e)$

Thus in an embodiment each pair of the 7 pairs in matrix F may be treated individually. For each $F_{k,1}$ or $H_{r,1}$ there is a list of target handover cells $(H_{s,2})$ which may or may not be included in matrix F; and $H_{r,1} \rightarrow H_{s,2}$ (or $F_{k,1} \rightarrow H_{s,2}$) is a pair of neighbouring relations. For each relation, the chance of successful handover i.e. $H_{q,3}$ / m(r) is multiplied by signal strength corresponds to $F_{k,1}$ which is $F_{k,2}$. Thus the calculation involves handover from one of the seven cells in matrix F. In this embodiment Matrix W includes all 7 cells of Matrix F when d=0 to 6 (i.e. serving cell and 6 neighbouring cells included in the nmr) and also all target handover cells neighbouring those 7 cells (i.e. from d=7 onwards).

Phase 3 searches the THREE cells $(Z_{e,1})$ with maximum values of $(Z_{e,2})$. These cells are used to identify the mobile station's location. The locations of these THREE cells form the vertices of a triangle. The resulted location is the centroid latitude and longitude of the triangle.

The vector quantization 350 makes use of a codebook, which models the radio characteristics of some specific sea-front regions in the GSM network, for future look-up by the compressed measurement reports 310. If the codeword is valid (352), the resulted location 370 is retrieved from the codebook immediately. Otherwise, the default Algorithm 340 is used. Vector quantization can be regarded as a form of pattern recognition where an

input pattern is "approximated" by one of a predetermined set of standard patterns, or in other words, the input pattern is matched with one of a stored set of templates or codewords. A vector quantizer Q of dimension k and size N is a mapping from a vector (or a "point") in k-dimensional Euclidean space, R^k, into a finite set C containing N output or reproduction points, called code vectors or codewords. Thus, $Q:R^k \rightarrow C$, where $C = (y_1, y_2, ..., y_N)$ and $y_i \in J \equiv \{1, 2, ..., N\}$. The set C is the codebook or the code and has size N, meaning it has N distinct elements, where each is a vector in R^k. The resolution, the code rate, or, simply rate of a vector quantizer is $r=(\log_2 N)/k$, which measures the number of bits per vector component used to represent the input vector. This gives an indication of the accuracy or precision that is achieved with a vector quantizer where the codebook is well-designed.

The codebook is typically implemented as a table in a digital memory and the number of bits of precision used to represent each component of each code vector does not affect the resolution or the bit-rate of the vector quantizer. In the present embodiment, every codeword in the codebook C represents a point in a sea front region, for example. Each codeword comprises a variable number of entities since the number of perceived cells varies from point to point. However, each entity

comprises the cell identity and its received signal strength as perceived by the mobile station in ·that geographical region. The codebook is $C = (y_1, y_2, ..., y_N)$ where $y_i = \{(c_1, s_1), (c_2, s_2), (c_3, s_3), ..., (c_{m(i)}, s_{m(i)})\}$. The codewords are collected using data derived during extensive drive tests and walk tests along pre-defined routes within the network. The entire codebook is updated regularly in order to remain current and valid, despite any changes caused by network expansion or network re-configuration.

The current valid NMR 310 collected from the SIM Application Toolkit (STK) is checked against the codebook, initially using the cell identities. Although each NMR has at most seven cells' identities and received signal strength values, it is common that less than seven cells' information can be received or decoded in practice due to many reasons, including radio interference. If too few cell identities are decoded from the NMR, the resolution for Vector Quantization 350 is regarded as too low for a reliable output. Therefore, only NMR with three or more cell identities is used for Vector Quantization in this embodiment.

In any case, multiple codewords are matched with a certain number of cell identities in a current NMR, and

the deviations from the quantization level, signal strength values are used to determine the closest match.

5   The locating system 230 provides resulted locations in terms of longitude and latitude. However, it is sometimes more user-useful in practical applications to have an area name rather than a numerical result. In that case, Area Mapping Module 240 maps the resulted location to an area by using the network profile database 142. If a single point is to be traditionally searched, throughout the entire digital map of the concerned country or city, substantial memory space and long searching time are needed. Thus, instead of using a traditional search, a two-step searching algorithm is used as follows, in order save memory space and to speed up the searching time required.

STEP 1: An initial search is made at a relatively low resolution. This is equivalent to dividing an entire map into a number of big squares. Longitude and latitude is then checked against corners of the squares to find the nearest square for the resulted location.

STEP 2: The first step acts as the table index search. There are a number of tables storing detailed location points relating to area information. The square found in STEP 1 corresponds to a particular table, which is

then be loaded into a memory for more specific location searching.

This two-step searching algorithm enables the area mapping module 240 to be implemented in the same platform of memory 230, which is Java$_{\wedge}^{(tm)}$. A single platform implementation allows use of a more consistent and reliable software design, which is less subjective to program incompatibilities, software version updates and maintenance problems.

Alternatively as mentioned earlier, the area mapping function can also be accomplished by a function call from MapInfo, which is a known geographical displaying tool. Whenever the resulted location is inputted, the function quickly maps to one of the pre-defined area objects and returns the area name. It is necessary to build an interface between the memory 230 and the area mapping module 240. The interface can be implemented in two possible ways, for example, one way is based on Visual Basics 6.0 and the other way is written by Visual C++.

CLAIMS

1. A locating system for a mobile station which comprises a locating system computer, the system supplying a normal network measurement report (NMR) for the mobile station to the computer, comparing the NMR with a network profile database, and computing resulted latitude and longitude for the mobile station where a suitable comparison is found.

2. A locating system according to claim 1, including the steps of validating and synchronising the NMR prior to supplying the NMR to the computer.

3. A locating system according to claim 1 or 2, in which the locating is carried out using a network statistics database for comparison in the computer, the database is derived using an algorithm to find the cell identity (ID) of seven most important adjacent cells, as measured by the mobile station, applying network handover statistics to calculate vicinity information of each cell, selecting the three nearest cells according to the calculation, and providing the resulted latitude and longitude as a centroid of the latitudes and longitudes of the three cells.

4. A locating system according to any of claims 1 to 3, including comparing the NMR with a vector

quantization (VQ) code book that contains codeword locations for cells located at special regions of the network, providing the resulted latitude or longitude based on any matching cell ID only.

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5. A method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising the steps of identifying three cells in the vicinity of the mobile station, each said cell 10 having a cell location; and determining an approximate position of the mobile station using the locations of the three cells.

6. A method as claimed in claim 5, wherein the 15 approximate position of the mobile station is determined by calculating a centroid of a triangle formed by said three cells.

7. A method as claimed in claim 5 or 6, wherein the 20 said three cells are selected from a plurality of candidate cells neighbouring a serving cell for the mobile station.

8. A method as claimed in claim 7, wherein a said 25 neighbouring cell is determined using at least one system parameter relating to the mobile station selected from a group including an ID of the serving cell, an ID of a base station in communication with the

mobile station, and a candidate neighbouring cell frequency channel.

9. A method as claimed in claim 7 or 8, wherein a said neighbouring cell is determined using a database (142) comprising cell mapping data defining physical cell locations.

10. A method as claimed in any one of claims 7 to 9, wherein the said three cells are selected from six candidate neighbouring cells.

11. A method as claimed in any one claims 7 to 10 further comprising measuring, for each neighbouring cell, a signal strength for a signal transmitted between the mobile station and the neighbouring cell; and selecting said three cells using the measured signal strengths and a database (144) of cell-to-neighbour-cell handover statistics.

12. A method as claimed in claim 11 further comprising calculating, for each neighbouring cell, a value representing a probability of a successful handover to that cell, and wherein said selecting is responsive to the calculated probability.

13. A method as claimed in claim 5 wherein, responsive to the identity of a cell serving the mobile station indicating that the mobile station is close to a sea front region or other predetermined special site, the approximate position of the mobile station is determined using only the serving cell identity rather than by identifying three cells in the vicinity of the mobile station.

14. A method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising the steps of using a compressed system parameter report to look up an approximate mobile station location in a vector quantization codebook.

15. A method for approximately locating a mobile station (MS) in a cellular mobile communications system, comprising selecting one of a plurality of location - determining algorithms responsive to the identity of a cell serving the mobile station.

16. A method as claimed in any one of claims 5 to 15 for approximately locating a mobile phone in a mobile phone network.

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17. A method as claimed in claim 16 wherein the mobile phone network is a phone network using GSM protocols.

18. Apparatus for carrying out the method of any one of claims 5 to 18.

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19. Software on a data carrier for carrying out the method of any one of claims 5 to 17.

Application No: GB 0007111.8   **Examiner:** Adam Tucker

Claims searched: 1-4   **Date of search:** 26 October 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

    UK Cl (Ed.S): H4L LRPLS, LDGR, LDPB

    Int Cl (Ed.7): H04Q 7/38, H04M 3/42, 11/08, G01S 5/14

Other: Online: WPI, EPODOC, PAJ, IEEE and selected internet sites

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, E	GB 2353671 A	(ROKE MANOR) See in particular page 12 line 1-page 13 line 29	1, 2
X	GB 2239758 A	(STC plc) See in particular page 1 line 26-page 2 line 25, page 3 lines 4-19 and page 5 lines 12-21	1, 2
X	WO 98/15149 A1	(NOKIA) See in particular page 4 line 24-page 5 line 14, page 5 line 33-page 6 line 30	1, 2
A	WO 97/24010 A1	(BELL) See in particular page 4 lines 7-29, page 12 line 16-page 16 line 4	-
X	WO 96/39638 A1	(AIRNET) See in particular page 3 lines 16-28, page 6 line 32-page 7 line 3, page 7 lines 13-23, page 9 line 21-page 10 line 18 and page 11 line 31-page 12 line 8	1, 2
A	JP 10262007	(NIPPON) See in particular enclosed PAJ translation of Means of the invention	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Category	Identity of document and relevant passage	Relevant to claims
A	http://www.simpleteam.com/download/en_300940v070700-04.08.pdf, GSM/ETSI Mobile interface layer 3 specification GSM 04.08 version 7.7.0 release 1998, Global System for Mobile Communications, See pages enclosed	1, 2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.